mirrors may be used if it the desired anti-parallelism may be otherwise maintained, although the retro prism 6 shown in Figure 1 is preferred as it provides a reliable retro-reflection without very great alignment efforts.

After the second pass through the etalon 4, or other interferometric device, the beam is input into a grating or etalon spectrometer 8. The apparatus function of the beam may then be determined. Figure 2 schematically illustrates an apparatus function measured by the double-pass etalon arrangement schematically illustrated at Figure 1. The free spectral range (FSR) of the etalon 4 was 5 pm and the finesse of the etalon 4 was 50 for performing the measurement shown in Figure 2. The radiation incident upon the spectrometer is greatly reduced as a result of the second pass through the etalon 4 as compared with a single pass arrangement.

Another application of using an interferometric device such as an etalon, or an interferometric device not having parallel plates, configured into a multi-pass arrangement is in the measurement of the spectra of narrow band lasers. Advantages include a high dynamic range (comparable with a grating spectrometer) and compactness.

TWO EXAMPLES ARE SHOWN IN FIGURE 3 AND FIGURE 5

Figure 3 schematically illustrates a triple-pass etalon arrangement according to a preferred embodiment. As with the double-pass arrangement schematically shown in Figure 1, the interferometric device 4 may be an etalon or alternatively a device not having parallel plates across the entirety of the interferometric reflecting surfaces, such as may be described in the '803 and/or '398 applications mentioned above. As shown in Figure 3, a narrow band and/or tunable laser beam, or other laser beam wherein it may be desired to know the wavelength, bandwidth, spectral purity or other spectral parameter of the beam, or wherein it is desired to measure the apparatus

function of the beam, traverses the etalon 4 on a first pass, and after retro-reflection, traverses the etalon 4 on a second pass, just as was described above with reference to Figure 1. After traversing the etalon 4 on the second pass, the beam is incident upon a second retro-reflector 10 preferably having the same specifications as, or that are similar to, the first retro-reflector 6 (see above description). The beam is retro-reflected by the second retro-reflector 10 preferably within 0.1° or less of perfectly anti-parallel to the beam incident upon the second retro-reflector 10. The beam passes through the etalon 4 on a third pass and is then incident upon a detector 12. As will be described in more detail below with reference to Figure 5, the detector 12 may be an array detector or a photodiode. If the detector 12 is a photodiode, then the etalon 4 may be pressure- or otherwise-tuned so that the detector measures the intensity of the beam at multiple FSRs, such as over 2-4 FSRs, of the etalon 4, or the wavelength of the laser may be tuned so that the detector 12 measures the intensity of the beam at multiple wavelengths.

In order to avoid line-broadening resulting from the multi-pass through the etalon 4, either in the double- or triple-pass arrangements shown schematically at Figures 1 and 3, respectively, the following measurement conditions are preferably maintained. First, line broadening due to beam divergency $\Delta\Phi$ as well as the line line shift due to deviations $\Delta\alpha$ of the incidence angles of the different passes are less than 0.1 times the passive bandwidth of the single pass etalon, e.g., (0.1 • FSR)/finesse. $\Delta\Phi$ and $\Delta\alpha$ may be preferably estimated from the etalon equation:

$$\Delta\Phi, \Delta\alpha < 0.3 \bullet (FSR/\lambda \bullet \text{finesse})^{0.5}.$$

For exemplary values λ = 193 nm, FSR = 3 pm, and finesse = 25, $\Delta\Phi$, $\Delta\alpha$ would be preferably maintained at less than approximately 0.25 mrad. If the above conditions are maintained, the spectral apparatus functions for single-, double- and triple-pass arrangements are depicted in Figure 4a which shows plots of spectral apparatus functions measured by single-, double- and triple-pass etalon

apparatuses; the double- and triple-pass apparatuses being according to preferred embodiments. Figure 4b shows integrated spectra of the plots shown in Figure 4a. The bandwidths for the three arrangements are shown in a legend in Figure 4a, i.e., for single-pass, the full width at half maximum (FWHM) is 0.06 pm, for double-pass, FWHM is 0.04 pm and for triple-pass, FWHM is 0.038 pm (for λ = 193 nm, FSR = 3 pm, and finesse = 25). The spectral purities for the three arrangements are shown in a legend in Figure 4b, i.e., for single-pass, the spectral purity (E95) is 0.35 pm, for double-pass, E95 is 0.05 pm and for triple-pass, E95 is 0.03 pm (again for λ = 193 nm, FSR = 3 pm, and finesse = 25).

Figure 5 schematically shows a double-pass etalon arrangement according to a particularly preferred embodiment. Laser radiation is incident upon a lens 14 that focuses the laser radiation onto an input face of a light guidance cable 16 such as an optical fiber. The laser radiation may be otherwise incident upon the input face of the light guidance cable 16 as understood by those skilled in the art. The light is guided along the light guidance cable 16 and exits at an output face. The light exiting the output face of the light guidance cable is expanded by a beam expander 18 that may preferably be a pair of lenses, or may alternatively include one or more prisms or reflective optics. The lens 14, light guidance cable 16 and beam expander 18 may or may not be used, such as is illustrated at Figures 1 and 3.The beam expander 18 preferably reduces the divergency to a level less than 0.25 mrad (see above).

The expanded beam is incident upon an interferometric device 20 such as preferably an etalon, and alternatively an interferometric device including non-parallel reflecting plates. The etalon 20 is preferably disposed within a housing 22. The housing 22 preferably includes at least one port 23 for inserting or removing gas for controlling the pressure within the housing. The pressure may be maintained constant, such as by sealing the housing or closing a valve to the port 23 or by having a constant flow of gas through the housing, wherein the wavelength of the laser radiation is instead tuned